AMD

Smashing the Barriers of 32-bit Gaming





GDC 2003
Mike Wall
Member of Technical Staff

Agenda

- Upcoming AMD Opteron™ and AMD Athlon™ 64
 - *Instruction set architecture*
 - *Processor Overview*
 - *Platform features*

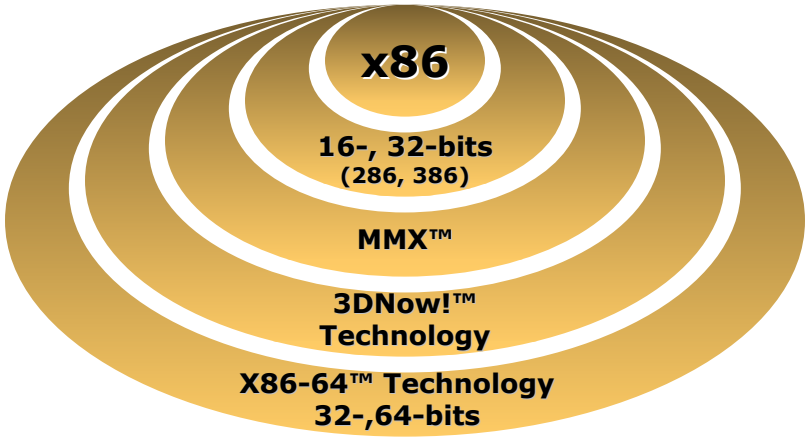
- Upcoming AMD Opteron and AMD Athlon 64 Processors for *Gaming*

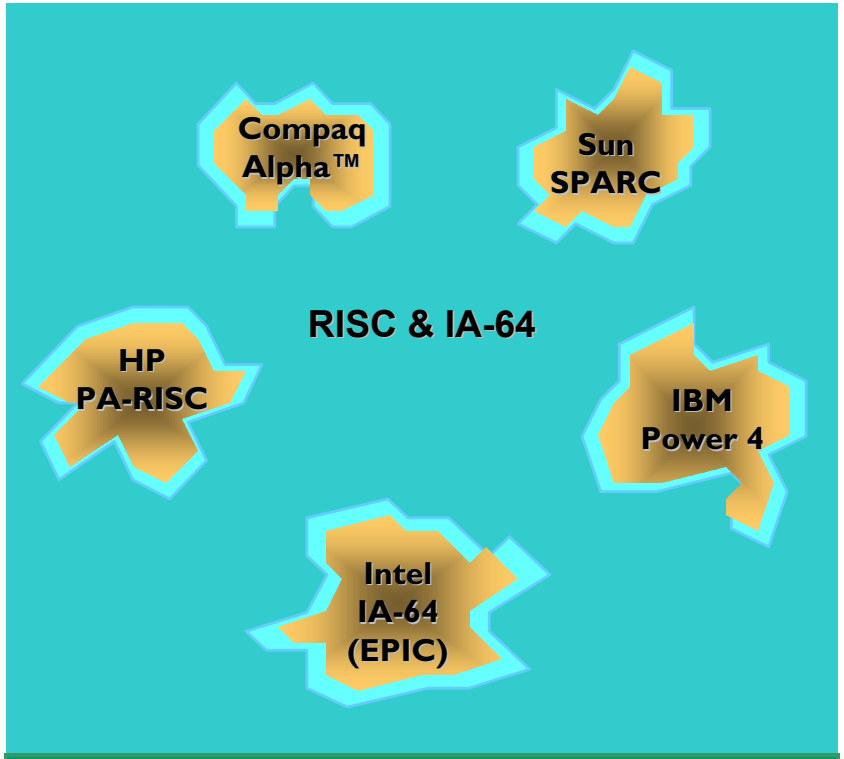
AMD 64-bit Technology Instruction Set Architecture

AMD 64-bit Technology transition

AMD

AMD's x86 Technology
Family of Processors





- A natural evolution of the current 32-bit architecture
- Similar to the 16- to 32-bit conversion of the 386
- Designed to retain compatibility with the current installed base of x86 operating systems and applications
- Low risk and low-cost path to high-performance computing

- There are many other 64-bit RISC solutions
- Each is a unique instruction set, all of which are incompatible with today's 32-bit code
- All require unique OS and applications

Managing Transition to AMD 64-bit Technology

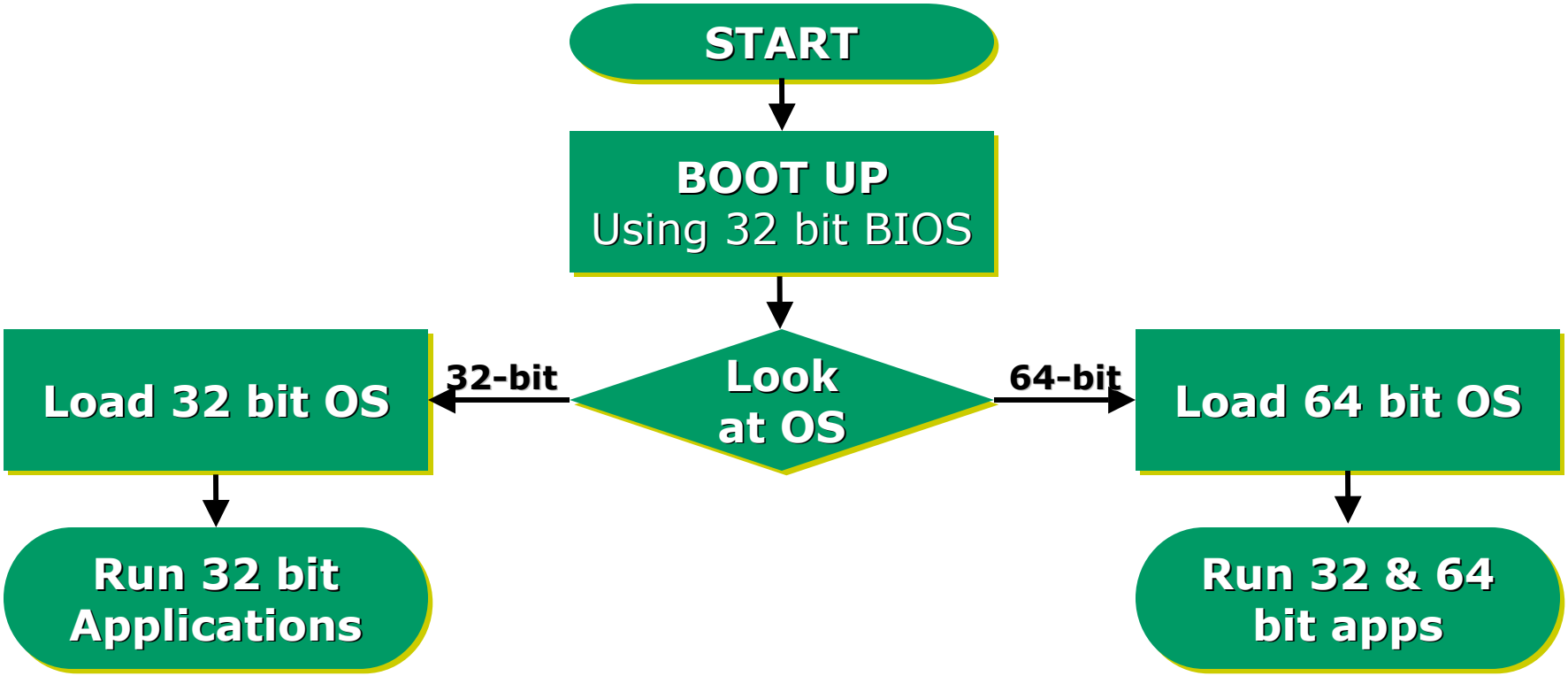
- Transition to 64-bit computing will occur at the pace of demand for its benefits

- Transition from 286 to 386 is the perfect analogy
 - 386 was an initiative to create 32-bit capable processors
 - Initial users enjoyed highest performance 16-bit execution
 - Operating system and application development took time
 - Operating system support allowed 16-bit and 32-bit processes to co-exist and interoperate
 - 32-bit software is now the norm
 - Although the 386 was introduced in 1985, 16-bit compatibility was important for years

- Great compatibility combined with great performance is the only practical approach to introducing new capabilities

AMD 64-bit Technology: compatibility

An x86-64-based PC can run both 32- and 64-bit operating systems



64-bit Computing Strategy - x86-64

AMD

----------32-bit OS----------

- Legacy Mode
 - Upcoming AMD Opteron™ and AMD Athlon™ 64 processors will run any 32-bit legacy OS with leading-edge performance
 - Fully compatible with existing 32-bit applications, drivers, OS, BIOS

----------64-bit OS----------

- Compatibility Mode
 - Under control of a 64-bit OS, existing 32-bit applications can be run with leading-edge performance
 - No application recompile required, no emulation layer
- 64-bit Mode
 - Desired applications can be ported to leverage the full 64-bit capabilities of x86-64
 - Migrate only where warranted, and at the user's pace

Core Architecture - AMD 64-bit Technology

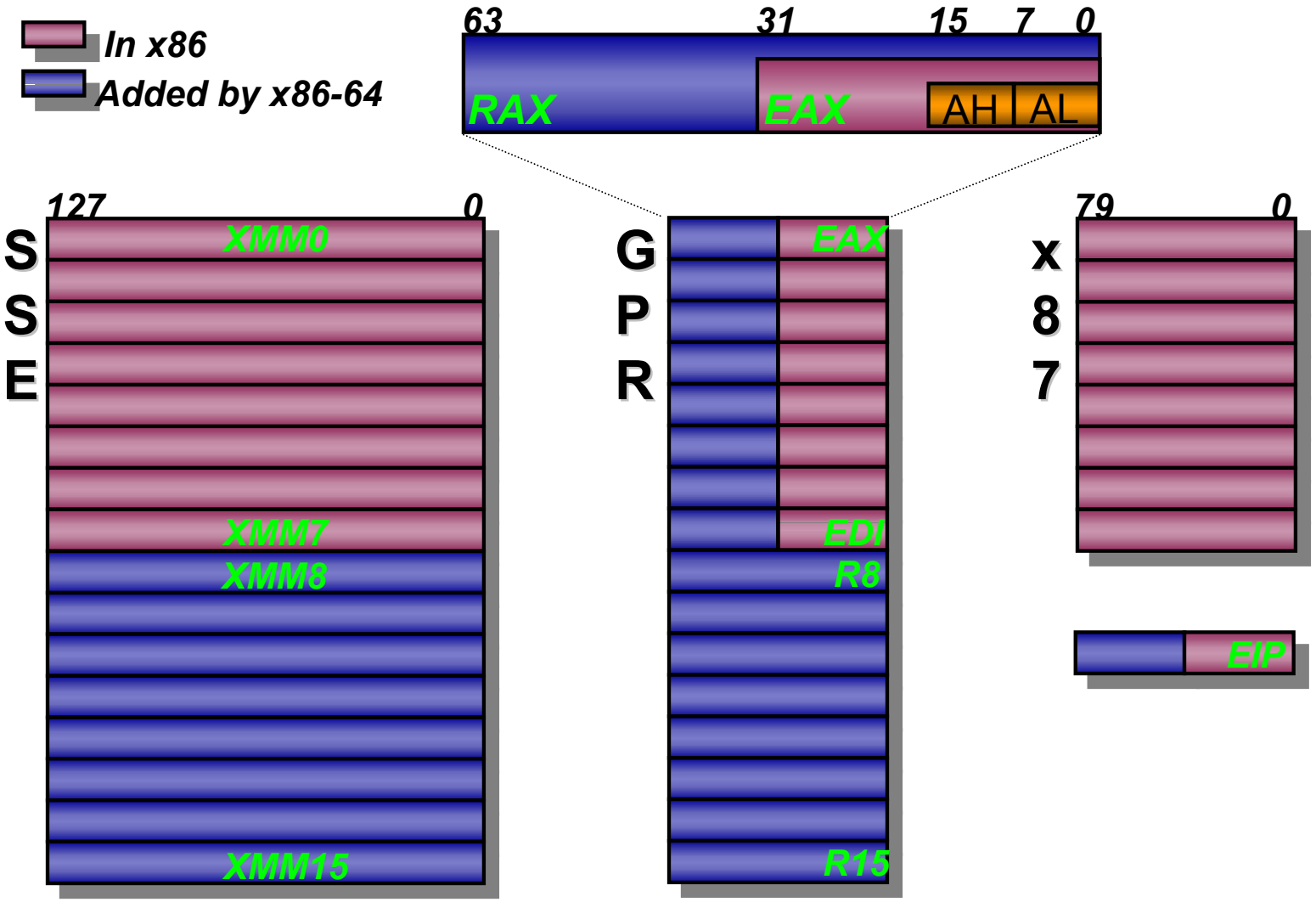
---------- 32-bit code and 64-bit code ----------

- SSE2 Instruction Set
 - New for the upcoming AMD Opteron™ and AMD Athlon™ 64 processors
 - Double precision scalar and vector operations
 - 16*8, 8*16 way vector MMX™ operations
 - SSE1 supported, already added with AMD Athlon XP, AMD Athlon MP, and Mobile AMD Athlon XP processors

---------- 64-bit code ----------

- 64-bit addressing
 - 64-bit integer registers/pointers
 - 48-bit virtual address (256 terabytes)
 - 40-bit physical address (1 terabyte)
- More Registers
 - Sixteen 64-bit general purpose integer registers
 - Sixteen 128-bit SSE registers
 - New ABI makes heavy use of new registers

x86-64 Programmer's Model



32-bit Considerations

- Improved x86 performance
 - 20-25% increase clock-for-clock compared to AMD Athlon™ XP processors
- Upcoming AMD Opteron™ and AMD Athlon 64 processors will include all SIMD instruction sets
 - MMX™, 3DNow!™, 3DNow! Professional (SSE), SSE2 technologies
 - Supports more software than any other x86 processor
- Maximum compatibility
 - Existing applications run without modification
 - No tools or OS work needed for 32-bit mode
 - Integrated memory controller and GART, so Windows® AGP miniport and Linux needed minor revisions
- Remember: Upcoming AMD Opteron and AMD Athlon 64 processor-based system is software-upgradeable to 64-bit operating systems and solutions

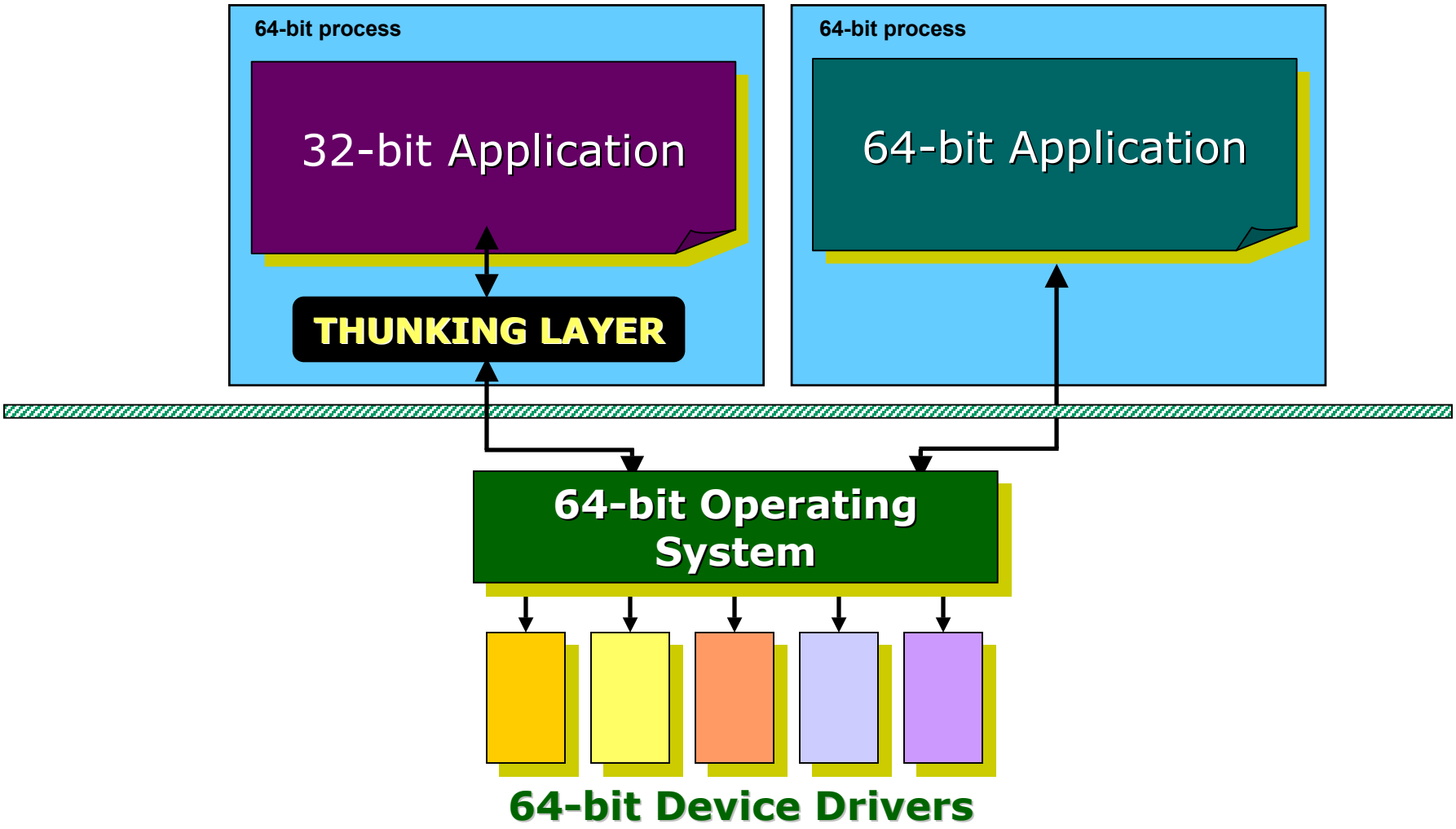
32-bit Compatibility

- Full compatibility with any 16- or 32-bit x86-based OS
- AMD validates over 50 OS releases including
 - Windows® (3.1, 95, 98, SE, Me, 2000 Pro, 2000 Server, 2000 Advanced Server, Server 2003, XP Home, XP Pro…)
 - Windows NT®, DOS, Linux, Unix …
- Full compatibility with millions of 16- and 32-bit
 - Games!
 - Applications
 - Devices and drivers
 - Extensive compatibility testing at AMD and by 3rd parties

64-bit OS Considerations

- No additional firmware (BIOS) requirements
 - Standard 32-bit BIOS
- 32-bit applications
 - Processor core provides full x86 compatibility, at full speed
 - OS provides thunking layer at kernel-call boundary
- 64-bit applications require 64-bit OS
 - Linux and Windows® operating systems
- Device drivers
 - 64-bit OS requires 64-bit device drivers
 - Firmware call-backs no longer supported
- 64-bit tools are new, but familiar
 - Simulation
 - Compilers, Linkers, Libraries
 - Debuggers, Performance analyzers

64-bit OS & Application Interaction

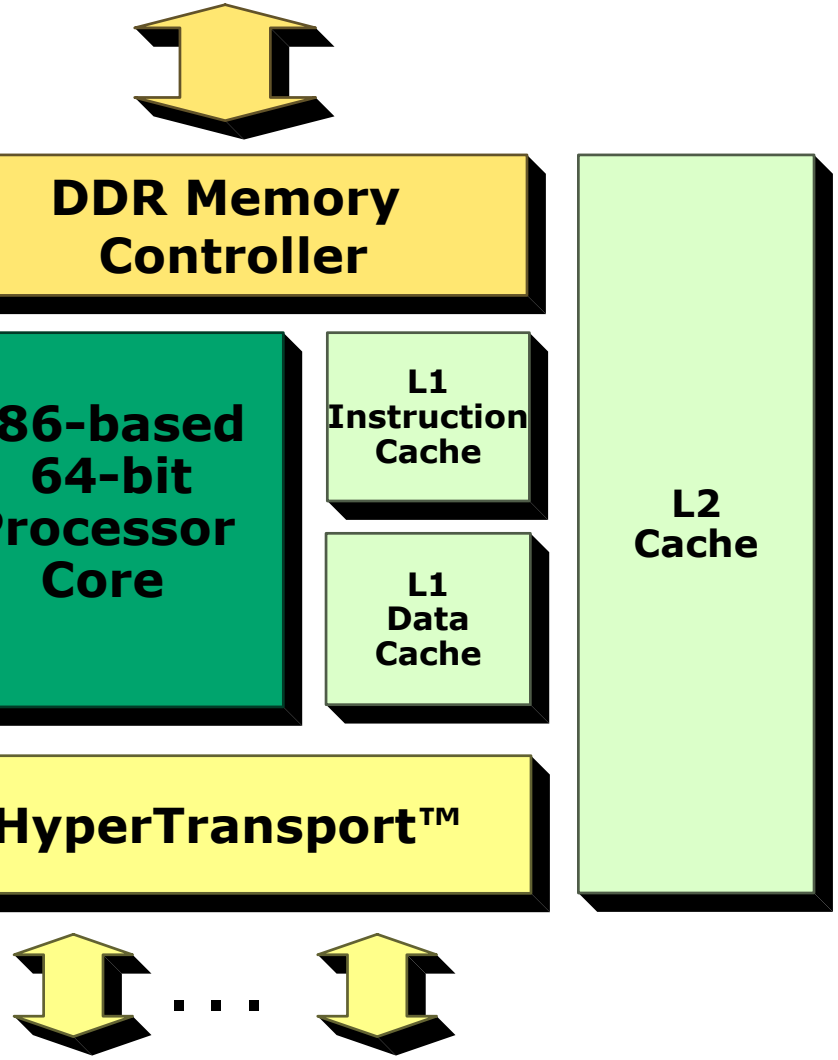


Compatibility Thunking Layer

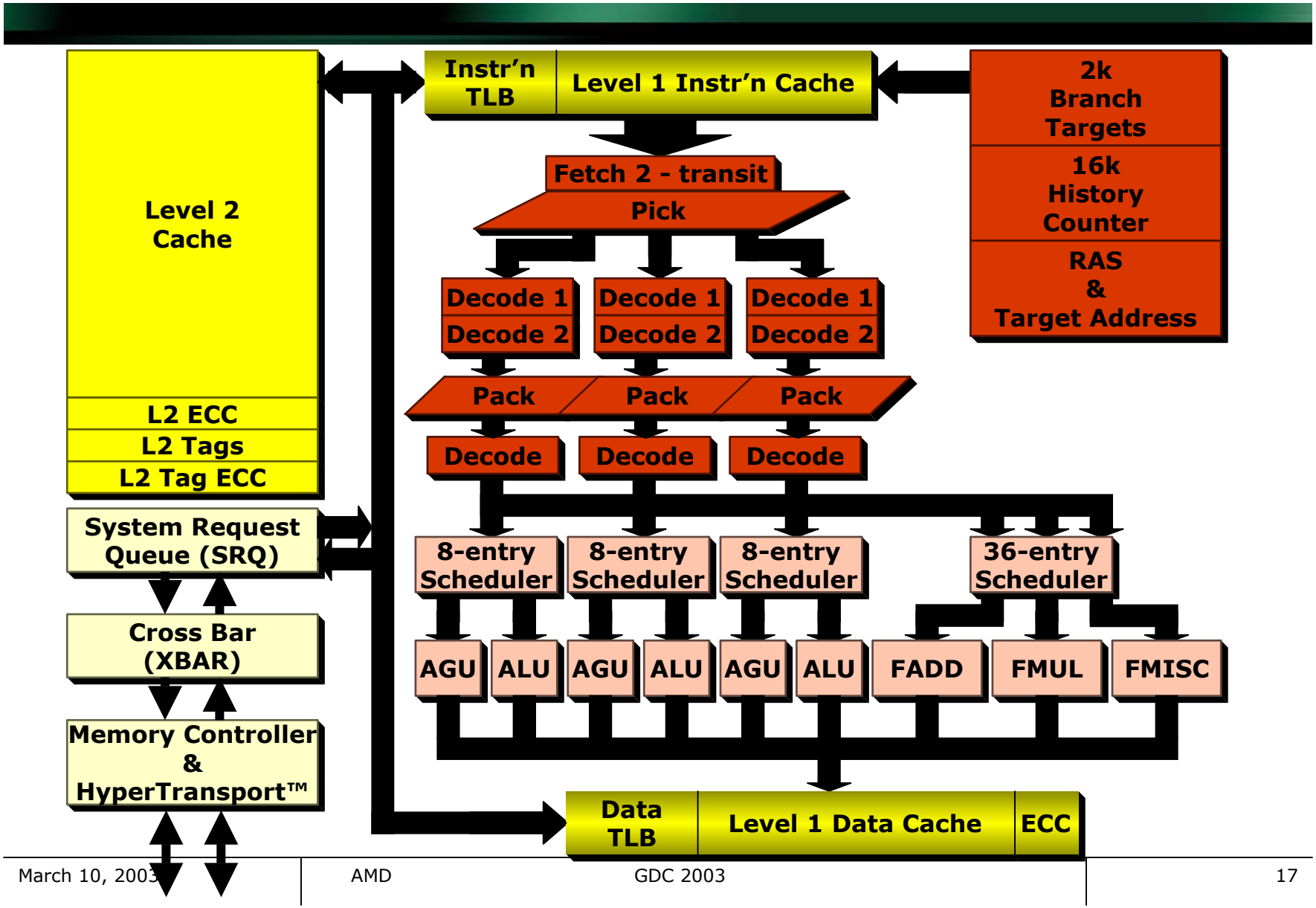
- A DLL integral to operating system
 - Transparent to end-user
- Resides within 64-bit process established to run 32-bit app
- 32-bit application is dynamically linked to Thunking Layer
- Thunking layer implements all 32-bit kernel calls
 - Translates parameters as necessary
 - Calls 64-bit kernel
 - Translates results as necessary
- Well understood technology implemented in many OS's
 - Windows®
 - Solaris
 - Linux

Upcoming AMD Opteron™ and AMD Athlon™ 64 Processors Overview

CPU Block Diagram



Processor Core Overview

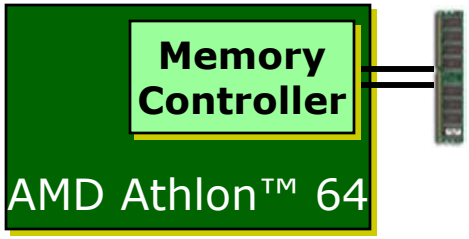


Integrated Memory Controller

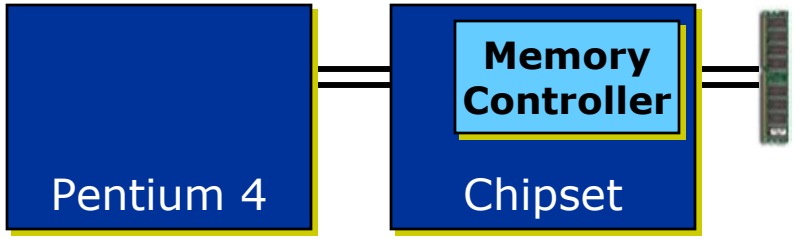
The word to remember:



1,000's of MHz
& Always Increasing



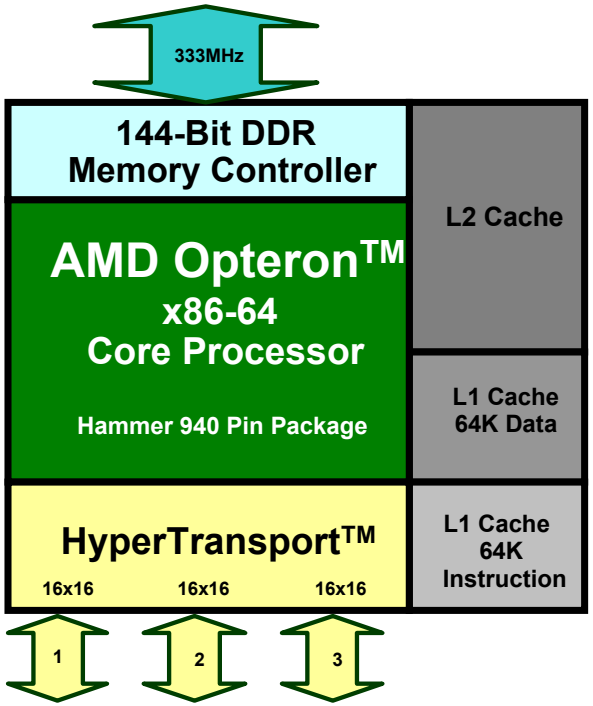
100's of MHz
& Not Improving



Integrated Memory Controller runs at CPU Core Frequency

- As the CPU frequency increases, the upcoming AMD Athlon 64 processor's memory controller becomes more efficient, but the Pentium 4 memory controller does not.

Upcoming AMD Opteron™ Processor Interface Capabilities



Per CPU Available Memory BW (M-Bytes/sec)			
	DDR200	DDR266	DDR333
AMD Opteron 128-bit	3200	4256	5328

Per CPU Available HT IO/MP BW (M-Bytes/sec)		
	IO BW	MP BW
AMD Opteron 3@16x16-Bit	6400	12800
Aggregate HT BWs shown		

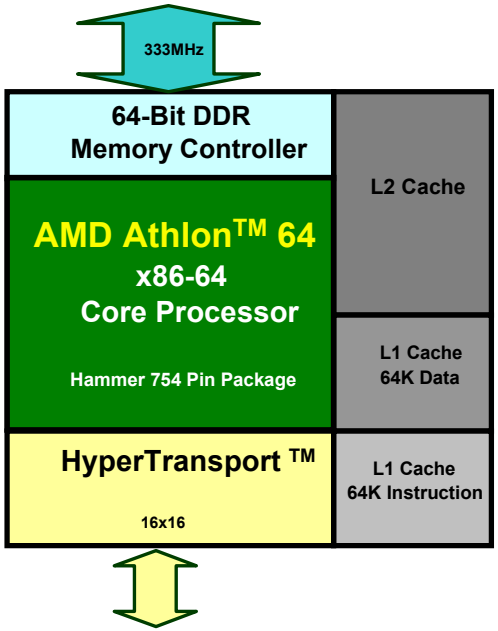
	Per CPU Memory Capacity Support (M-Bytes)				
184-pin DIMMs	chip density	128M-Bit	256M-Bit	512M-Bit	1G-Bit
AMD Opteron 144-bit Registered	8 modules	2048	4096	8192	16384

Upcoming AMD Opteron™ Processor

- AMD Opteron™ Processor
 - Up to 8-way Server-Class Processor
 - Two 72-bit DDR channels supporting 200, 266, and 333 MHz
 - Future memory technology support as it is defined
 - Three 16-bit HyperTransport™ technology links at 1600MT/s
 - A range of integrated L2 cache sizes including 1MB and larger
- 940-pin mPGA Package

NOTE: All Upcoming AMD Opteron processors support x86-64

Upcoming AMD Athlon™ 64 Interface Capabilities



Per CPU Available Memory BW (M-Bytes/sec)			
	DDR200	DDR266	DDR333
Athlon 64 64-Bit	1600	2128	2664

Per CPU Available HT IO/MP BW (M-Bytes/sec)		
	IO BW	MP BW
Athlon 64 1@16x16-Bit	6400	NA

Per CPU Memory Capacity Support (M-Bytes)					
184-pin DIMMs		128M-Bit	256M-Bit	512M-Bit	1G-Bit
64-Bit Unbuffered	2	512	1024	2048	4096
64-Bit Registered	4	1024	2048	4096	8192

Upcoming AMD Athlon™ 64 Processor

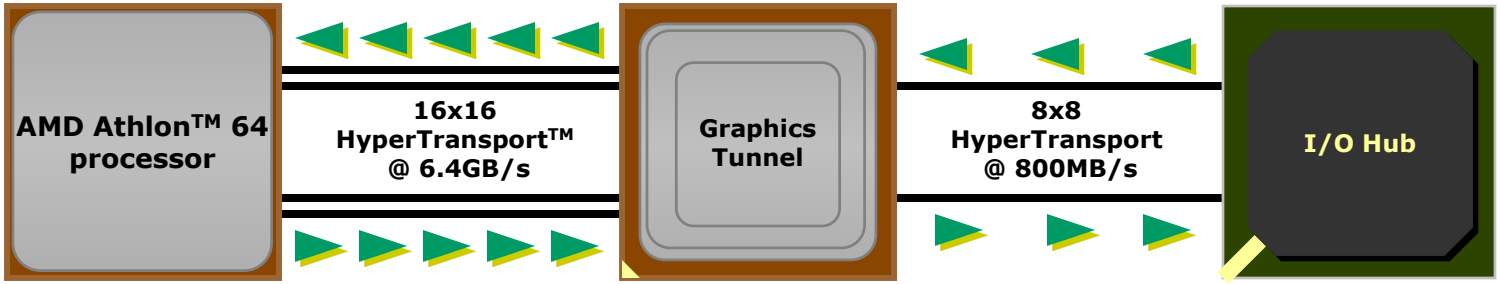
- Upcoming AMD Athlon™ 64 processor
 - Performance Desktop Processor
 - One 72-bit DDR channel supporting 200, 266, and 333 MHz
 - Future memory technology support as it is defined
 - One 16-bit HyperTransport™ technology link at 1600MT/s
 - A range of integrated L2 cache sizes

- 754-pin mPGA Package

NOTE: All Upcoming AMD Athlon 64 processors support x86-64

Upcoming AMD Opteron™ and AMD Athlon™ 64 Processor-based Platform Features

HyperTransport™ Technology Interface



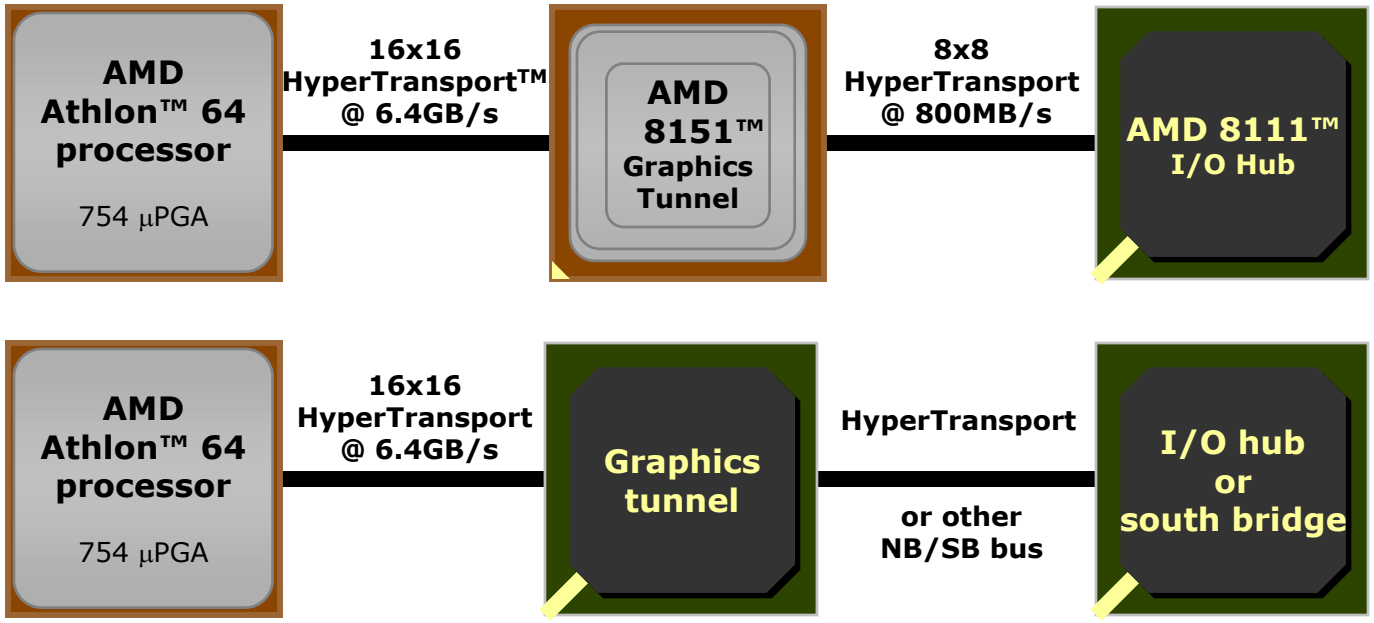
HyperTransport™ Technology Interface Attributes

Unidirectional

DDR-like performance (800MHz = 1600MT/sec)

4 bytes wide … 6.4GB/sec bandwidth

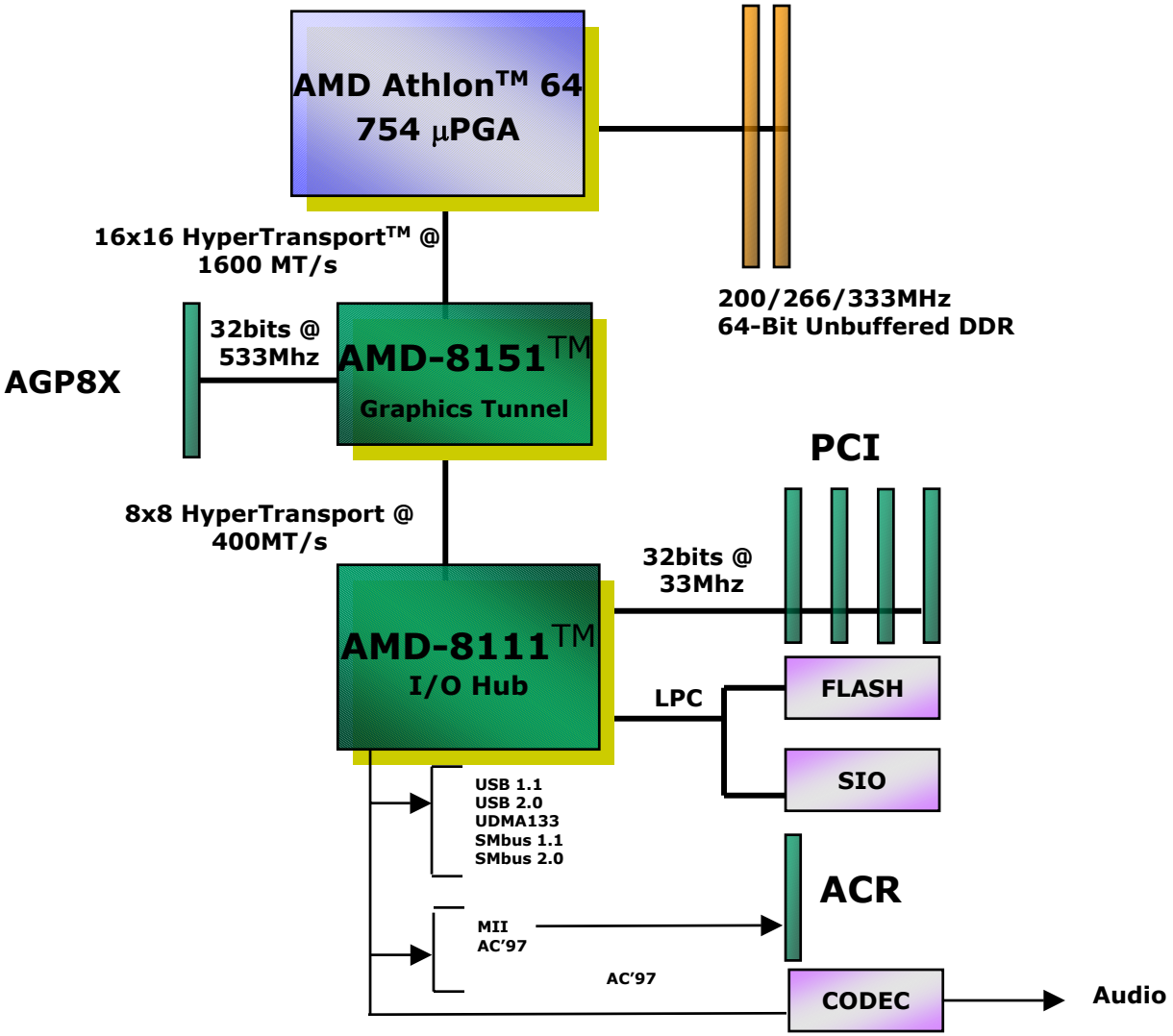
Chipset Interfaces: Upcoming AMD Athlon™ 64 Processor examples



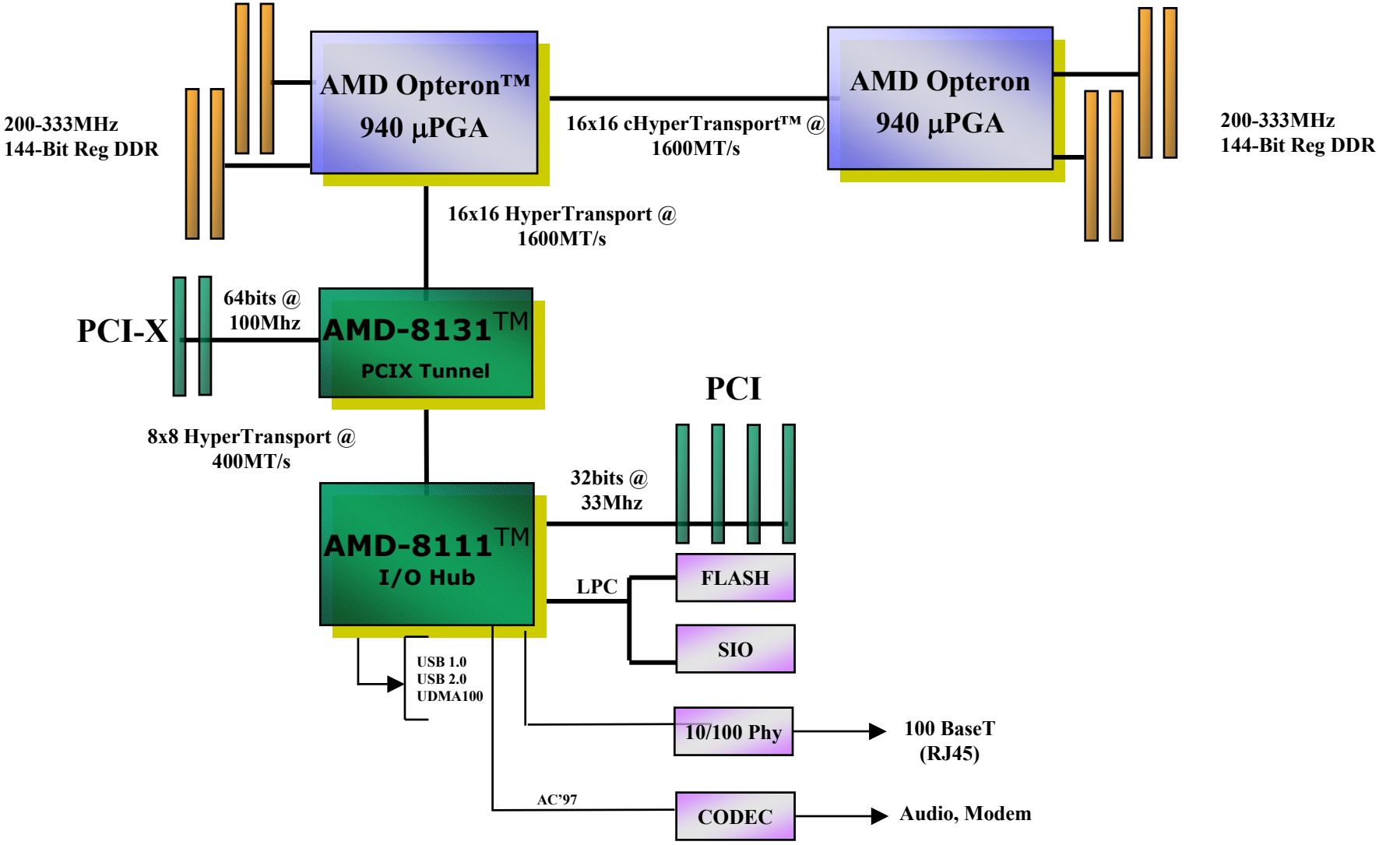
Chipset partners include:

- ✓ **NVIDIA**
- ✓ **ATI Technologies**
- ✓ **VIA**
- ✓ **SiS Corp.**
- ✓ **Ali Corporation**

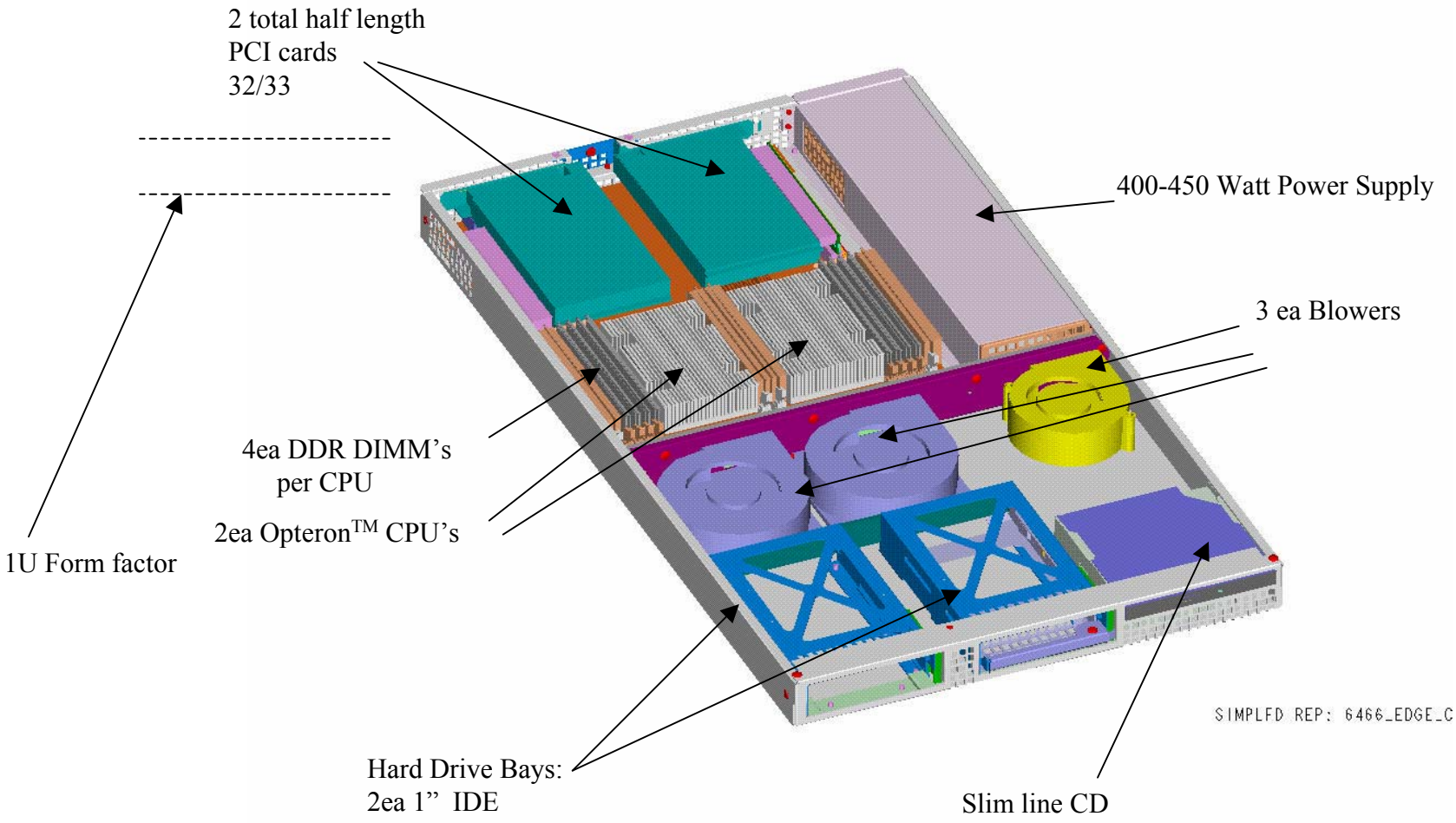
AMD Athlon™ 64 Processor-based Performance Desktop



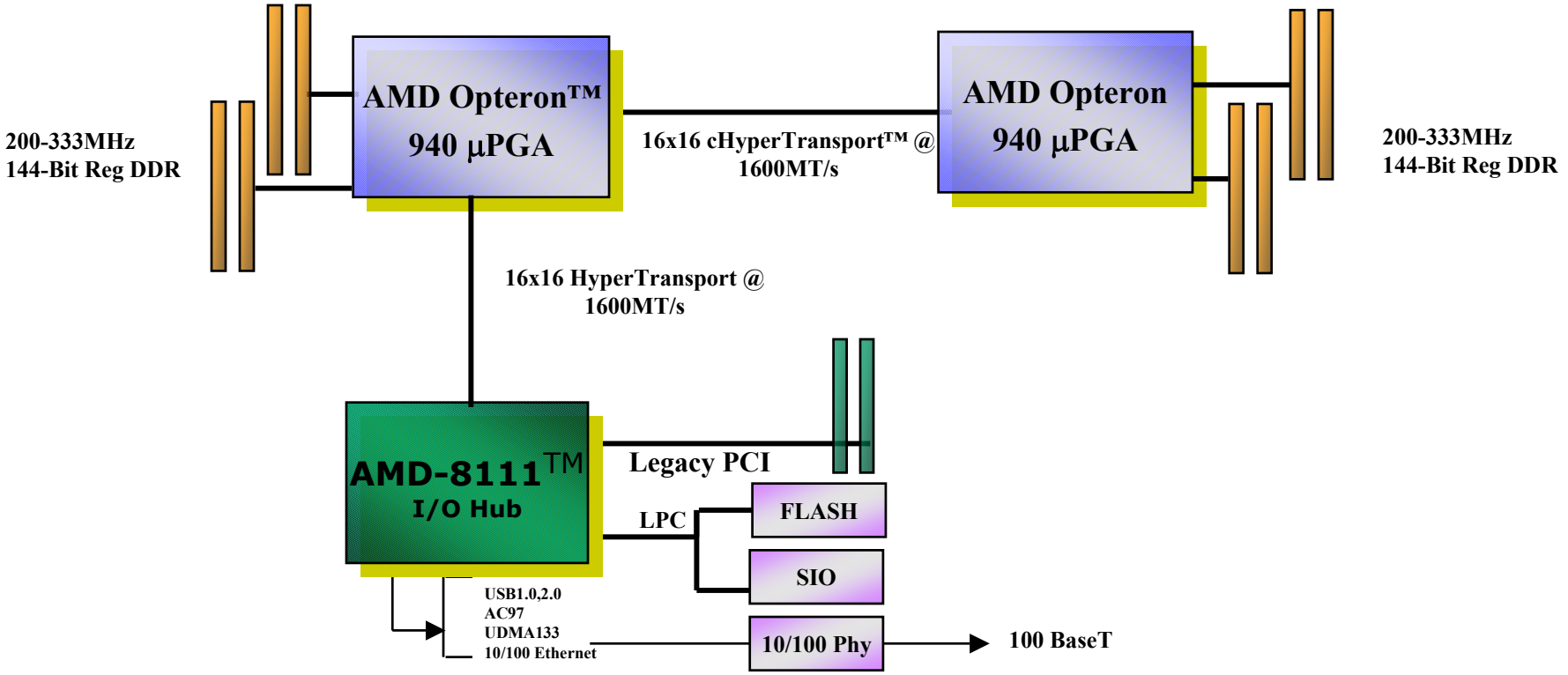
2P "System Builder" Server



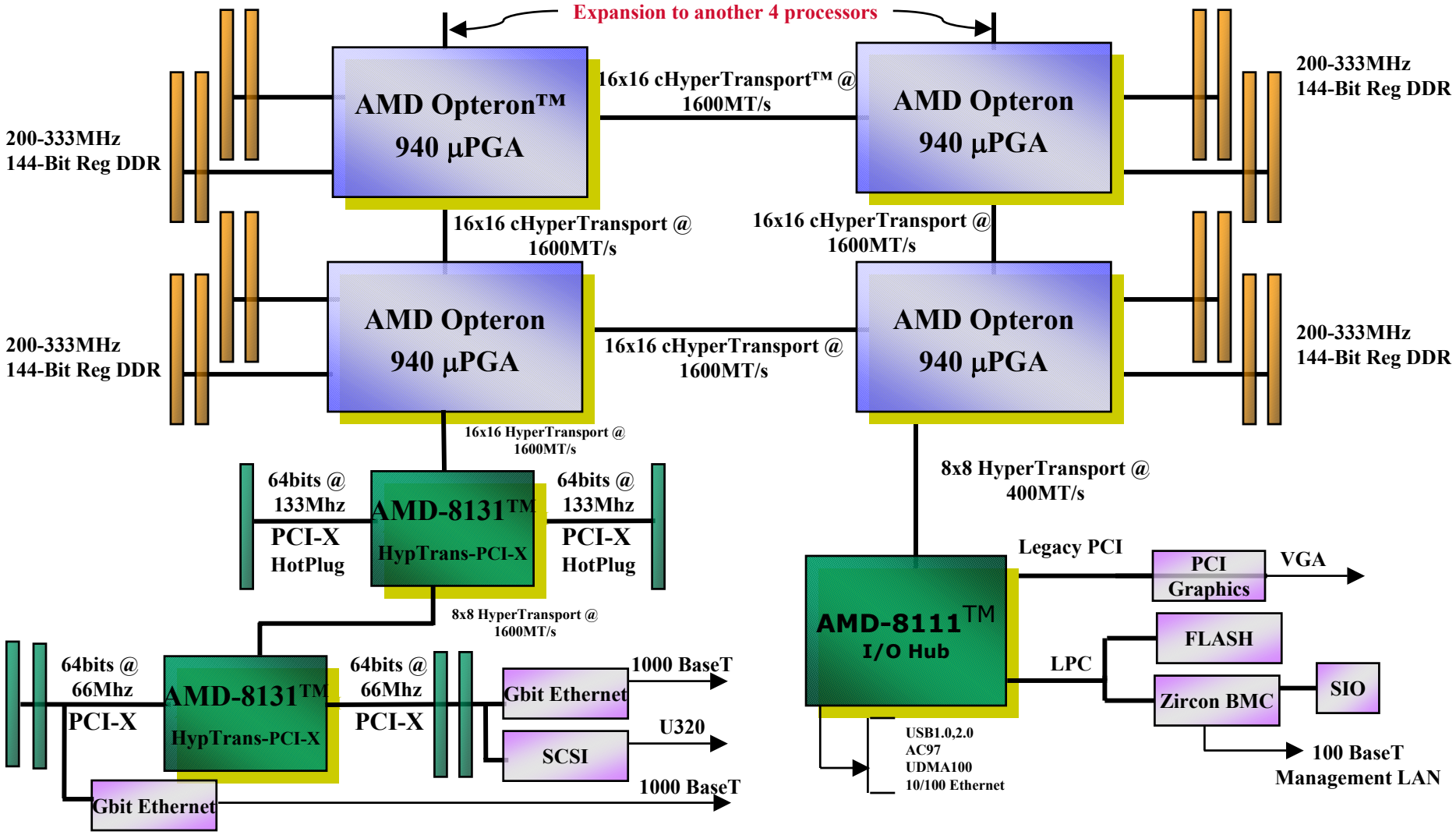
1U 2P System Builder Box Example



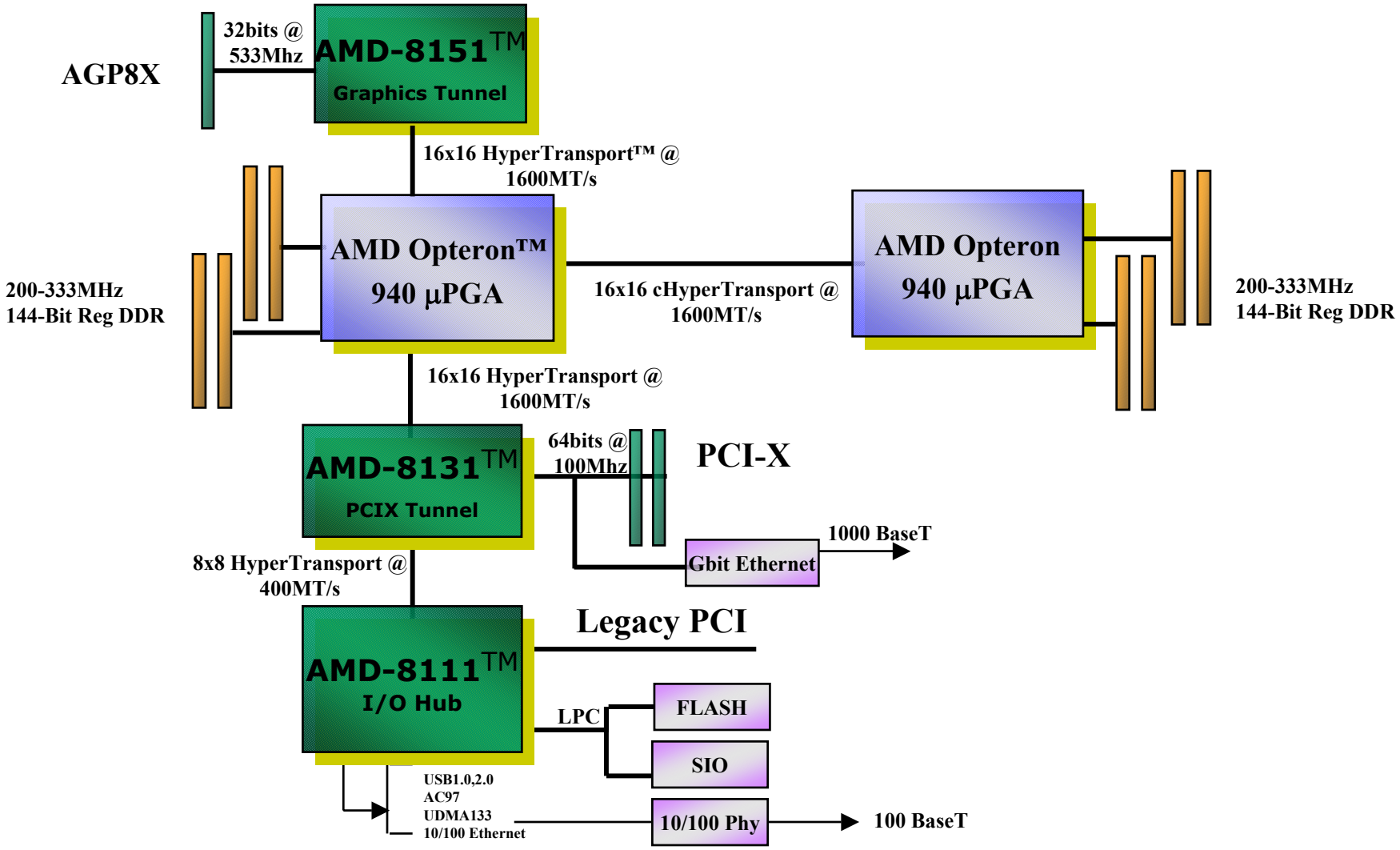
Low-Cost Server



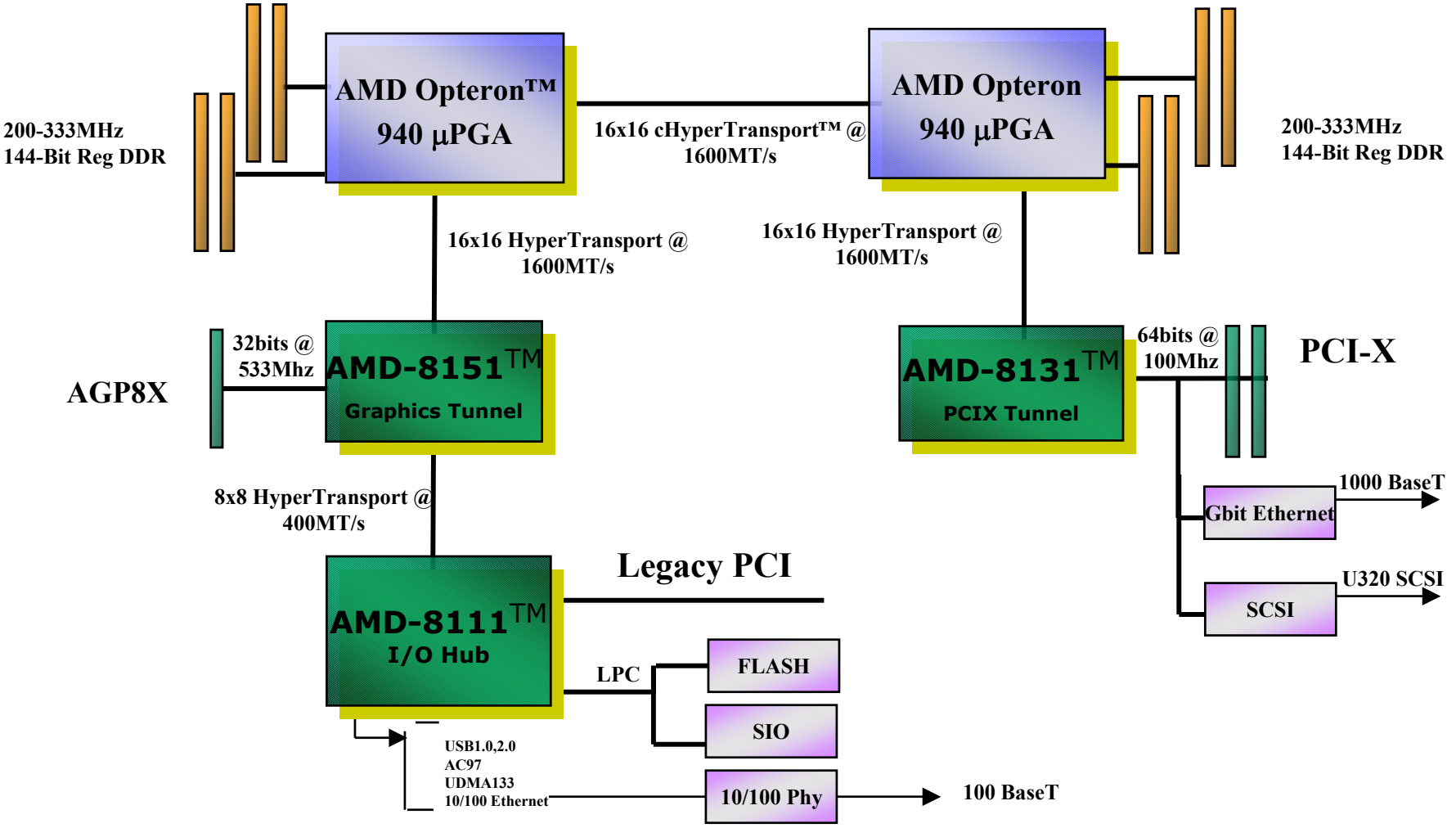
4P Server


Expansion to another 4 processors
AMD Opteron™ 940 µPGA
AMD Opteron 940 µPGA
AMD Opteron 940 µPGA
AMD Opteron 940 µPGA
16x16 cHyperTransport™ @ 1600MT/s
16x16 cHyperTransport @ 1600MT/s
16x16 cHyperTransport @ 1600MT/s
16x16 cHyperTransport @ 1600MT/s
200-333MHz 144-Bit Reg DDR
200-333MHz 144-Bit Reg DDR
200-333MHz 144-Bit Reg DDR
200-333MHz 144-Bit Reg DDR
16x16 HyperTransport @ 1600MT/s
8x8 HyperTransport @ 400MT/s
64bits @ 133Mhz PCI-X HotPlug
AMD-8131™ HypTrans-PCI-X
64bits @ 133Mhz PCI-X HotPlug
8x8 HyperTransport @ 1600MT/s
64bits @ 66Mhz PCI-X
AMD-8131™ HypTrans-PCI-X
64bits @ 66Mhz PCI-X
Gbit Ethernet
1000 BaseT
SCSI
U320
Gbit Ethernet
1000 BaseT
AMD-8111™ I/O Hub
Legacy PCI
PCI Graphics
VGA
LPC
FLASH
Zircon BMC
SIO
100 BaseT Management LAN
USB1.0,2.0
AC97
UDMA100
10/100 Ethernet

Expandable Workstation



High–Performance Workstation



Upcoming AMD Opteron™ and AMD Athlon™ 64 Processor Summary

64-bit x86-based CPU core

- High performance: optimum balance of IPC and MHz

AMD 64-bit technology

- Compelling 64-bit migration strategy without sacrifice of existing code base
- Full-speed support for x86 code base
- Unified architecture from notebook through server

DDR memory controller

- Significantly reduces DRAM latency, increases capacity

HyperTransport™ technology

- High-bandwidth I/O
- Glueless MP

Foundation for future portfolio of processors

- Top-to-bottom desktop and mobile processors
- High-performance 1-, 2-, 4-, and 8-way servers and workstations

What does all this mean for gaming?

Upcoming AMD Opteron™ and AMD Athlon™ 64 processor benefits for gaming

- Game development process
- Game servers
- Game PCs

64-bit in Game Development Process

Large memory space and fast multiprocessor machines:

- Faster compilation of software
 - Shorten the cycle time of *implement → build → test → repeat*
- Faster creation of complex game levels
- Faster 3D content creation
 - Modeling
 - Animation
 - Rendering
 - Example: mental images® GmbH mental ray® renderer
 - Example: Tim Sweeney from Epic

64-bit Servers

- Run 32-bit code and 64-bit code, side by side, at full performance

- A unified CPU and system architecture for server and client
 - Use identical tools for compiling server and client versions
 - Use the same code libraries
 - No issues with numeric precision
 - No issues with big-endian vs. little-endian data
 - No restrictive data alignment requirements

- Large memory capability: 16GB per CPU and rising
 - Enables more players per server
 - Enables larger, richer, more detailed worlds
 - Fewer server CPUs needed
 - Less space, less power, less cost

64-bit Servers



64-bit Game PCs

- Extra SSE registers and general purpose registers can improve performance
 - Physics simulation
 - Dynamics
 - Collisions
 - Cloth, water, smoke
 - AI
 - Codecs
 - Real-time multi-channel audio synthesis

- Large memory capability: 6GB in a PC and rising
 - Enables larger, richer, more detailed worlds
 - Seamless transition between game zones
 - Store huge amount of audio data in memory

- Example: Epic Games 

64-bit port: Ryan Gordon

Future potential of 64-bit gaming

AMD

- Living ecosystems with vast numbers of non-player characters
- Every object interaction is physically modeled
- Unique sounds are synthesized in real time, based on physics
 - Object properties determine basic waveform generated
 - Environment determines reflections, absorption, spatial aspects
- No more "fat pixels"
 - User interface promotes up-close inspection of everything
 - Fractal algorithms generate highly detailed geometry and textures, store them all in memory
 - Nearly unlimited detail, extremely immersive and believable
- Real-time speech input that works well

Microsoft likes AMD 64 bit technology

Jim Allchin, the man in charge of Microsoft's operating systems, calls the performance of software on the AMD machines "pretty amazing."

"We can give any 32-bit application an additional gigabyte of memory, and you don't have to write a single byte of code," says Allchin. Programs written especially for 64 bits get further "dramatic performance advantages," he says.

from Fortune Magazine, February 17

Stay tuned!

Porting isn't too hard

Getting ready to port…

- Compile your 32-bit game using the /Wp64 switch (Microsoft compiler)
 - Identify and remedy potential portability issues
 - This will even make your 32-bit code cleaner

- Use `unsigned int` instead of `int` when possible, e.g. array index
 - Use `size_t` for arrays that may grow beyond 32-bit limit

- Multi-threaded code should be "NUMA friendly"
 - The OS is smart enough to allocate local memory
 - Call malloc() from thread that will most heavily use the memory
 - Don't malloc all your application's memory from global process
 - This helps both 32-bit code and 64-bit code

Moving up to 64-bit mode…

- Compile your game using the 64-bit tools
 - Pointers become 64-bit data types, some data will grow
 - You need 64-bit versions of any code libraries used
 - Port any assembly code as separate asm files (no in-line)
 - Maintain sync between C/C++ and asm data structs
 - x86-64 assembly code is familiar, very much like x86
 - Use all the new registers for better performance!
- MigraTEC 64Express tool can help, especially with unfamiliar code
 - Automates the code audit process, tracks modifications

Moving up to 64-bit mode…



- Programming 64-bit Windows® is pretty much the same as 32-bit
 - The Windows API stays the same (a few data types change)
- Types `int` and `long` remain 32 bits in 64-bit Windows
 - Use `unsigned` 32-bit types where possible
- Only pointers expand to 64 bits
- Special polymorphic data types support pointer storage/math:
 - INT_PTR, UINT_PTR, LONG_PTR, ULONG_PTR

- A single source code tree: compile for 32-bit and 64-bit!

- Measure and optimize performance
 - AMD CodeAnalyst profiling tool available free (Q2 ’03)
 - Upcoming AMD Opteron™ and Athlon™ 64 processor opt. guide

Call to action

What should game developers do?

- Compile with /Wp64 for Windows®, get code "64-bit clean"
- Call malloc() from the right thread/process in multi-thread apps
- Unsigned `int` and `long` and `size_t` are your friend

- Get the 64-bit OS, tools, docs
- Scope out the project
- Evaluate the benefits
- Port your game!

➢ Tell your favorite OEMs what you want them to build
➢ Tell your software providers what you want

Call to action: tools and info

- 64-bit Windows® XP OS, Platform SDK, DDK, 64-bit Readiness Kit
 - x64info@microsoft.com
 - http://msdn.microsoft.com
 - Search for "AMD 64" or "porting to 64 bit" or "porting to Win64"
- 64-bit Linux OS, tools, docs
 - http://www.x86-64.org
- AMD tools and documentation
 - http://developer.amd.com
 - CodeAnalyst, Optimization Guide, Programmer's Manuals, other tech docs
- AMD Developer Center !
 - http://www.developwithamd.com/devcenter
 - Come to Sunnyvale, use our machines, talk to our tech people
 - Also support remote VPN access
- AMD Developer Relations
 - Connie Siu and Beatriz Hubert

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